Cognitive aftermath of ischemic stroke

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Verbal and non-verbal explicit learning, and picture priming after unilateral stroke

abstract

Despite growing interest in cognitive functioning after stroke, little is known about the course and nature of resulting learning deficits. Explicit learning in the subacute and chronic stage was assessed with the paired-associate learning of verbal (names) and non-verbal (faces) stimuli and by the Rey Auditory Verbal Learning Test. Implicit learning was studied using a priming paradigm. As hypothesized, explicit, but not implicit memory, was impaired in the patients compared to control subjects. These impairments appeared to be stable during the year following the stroke. The data did not confirm the expected effect of side of lesion on verbal versus non-verbal learning. Age, however, appeared to be an important predictor of explicit learning abilities: although older patients obtained the lowest memory scores, the impact of stroke was greater in younger patients.

The impact of unilateral ischemic stroke on explicit and implicit learning.

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Submitted.

Introduction

There is a considerable amount of evidence that stroke causes deficits in declarative memory (Hochstenbach, Mulder, van Limbeek, Donders, & Schoonderwaldt, 1998; Hom & Reitan, 1990; Kotila, Waltimo, Niemi, Laaksonen, & Lempinen, 1984; Steward, Sunderland, & Sluman, 1996; Tatemichi, et al., 1994; Wade, Parker, & Hewer, 1986; Wang, Joel, Kaplan, Eugene, & Rogers, 1975). Surprisingly little is known, however, about the course of memory functioning following ischemic stroke. Hochstenbach (1999) found that memory was the cognitive domain that showed the least improvement between two and 28 months post-stroke. In a study by Kotila et al. (1984) 55% of stroke patients had memory impairments three months post-stroke, this was reduced to 31% after one year. However, neither of these studies included a longitudinal assessment of a control group to discover possible retest effects. The first aim of this study was to assess the course of explicit learning between the subacute and chronic stages after a first ever, unilateral ischemic stroke in a community-based population.

Not many studies examining memory in stroke patients have focused on the traditional, and clinically important, comparison of hemispheric specialization; left hemisphere for verbal, and right hemisphere for non-verbal material (Kolb & Whishaw, 1996; Springer & Deutsch, 1993; Tranel & Damasio, 1995). Impairments in verbal learning were shown in left hemisphere stroke patients with aphasia as compared to non-brain damaged control subjects (Beeson, Bayles, Rubens, & Kaszniak, 1993), but also in left hemisphere patients without aphasia in comparison with right hemisphere patients (Hildebrandt, Brand, & Sachsenheimer, 1998). Impairments in verbal memory were found in right hemisphere stroke patients in one study (Welte,1993), but not in another study (Cappa, Papagno, & Vallar, 1990). Right hemisphere stroke patients did not demonstrate decreased recall scores compared to left hemisphere patients on the Rey Osterrieth Complex Figure, a non-verbal memory task (Lange, Waked, Kirshblum, & DeLuca, 2000). Several imaging studies suggest bilateral involvement in non-verbal episodic memory encoding, and in both verbal and non-verbal episodic memory retrieval (for a review see: Cabeza & Nyberg, 2000).

The use of a verbal and non-verbal task following the same paradigm would be the most informative method to study laterality effects. Steward and colleagues (1996) applied Warrington's Recognition Memory Tests for words and faces (RMT, Warrington, 1984). They demonstrated a selective impairment for the recognition of faces in the right hemisphere stroke patients, but no parallel disorder for the recognition of words in the left hemisphere group. Moreover, the number of patients that was impaired on the RMT subtests was very small, which might be a consequence of the fact that the test only assesses recognition (Steward, et al., 1996). One of the critical remarks that have been made about the RMT is its lack of sensitivity to lateralized brain damage (Sweet, Demakis, Ricker, & Millis, 2000) and a deficiency in distinguishing brain damaged patients from healthy controls

(Bouma, Mulder, & Lindeboom, 1996).Therefore, to investigate the effect of lesion lateralisation on the ability to learn verbal and non-verbal material, which is the second purpose of this study, the Couples Test, a new memory test, was developed. This paired-associate learning task uses names as the stimulus material for the verbal subtest and faces for the non-verbal subtest, but instead of recognition, subjects were asked to reconstruct the pairs.

While impairments in memory following stroke have been reported in several studies, there are data which indicate that implicit memory remains relatively intact. In a case study, Cushman and Caplan (1987) showed procedural learning to be unimpaired in a stroke patient with explicit memory problems. Moreover, implicit memory function involving word-stem completion priming tasks was relatively spared compared to explicit memory function in these patients (Cooley, Stringer, Hodnett, 1997; Curran, Schacter, & Gallucio, 1999). The Picture Fragment Completion Task (Snodgrass & Feenan, 1990) was used in the present study as a priming task to address our third goal: the investigation of implicit learning after stroke.

To summarize: the focus of this study was to assess the course of memory functioning after first-ever unilateral ischemic stroke, in a community-based patient group. We hypothesized that both left and right hemisphere stroke patients would show impairments in explicit learning as compared to a healthy control group. Moreover, we expected to find the greatest loss of memory for left hemisphere patients on the Names subtest, and for right hemisphere patients on the Faces subtest of the Couples Test. Additionally, all groups, controls and patients, were expected to perform better one year after the first assessment. If any recovery of memory was observed, this effect should be larger in the patient group. Finally, priming was hypothesized to stay intact after stroke.

Methods

Participants

In order to examine a community-based group, patients with a clinically diagnosed unilateral, first-ever, ischemic stroke were recruited from general practitioners (GPs) in the northern part of the Netherlands and from the stroke unit of the University Hospital in Groningen. The GPs and the stroke unit presented 235 stroke patients. Neurological and GPs' reports were examined. Patients who did not meet the criteria of having a unilateral, first-ever, ischemic stroke (n= 45) were excluded. Patients with previous small subcortical silent infarctions, which were evident from CT-data, were not excluded. Of the remaining 190 stroke patients 102 patients were included in the study. Of the 88 patients that were excluded, 29 did not meet the other inclusion-criteria (no other neurological disorders, psychiatric diseases, or substance abuse, and being able to keep up the testing procedures for at least half an hour), 52 dropped out because they either died before testing (n= 3), could not be reached (n= 6), or did not want to participate (n= 43), and 7 patients had such severe language deficits that they were unable to understand even the simplest test instructions. Finally, 6 patients had to be excluded because none of the memory tasks could be administered. One year after the first assessment 76 of the 102 subjects continued their participation in the study (4 had died, 4 were too weak, 1 suffered a second stroke, and 12 did not want participate any longer).

Control subjects (n= 72) were also recruited through the aid of GPs. They were included if they were clinically stroke free, had no neurological or psychiatric disorders, and no history of substance abuse. None of the control subjects was demented according to the Dutch Dementia Screening Test (CST-20, De Graaf & Deelman, 1991). One year later 64 subjects were tested again (4 were too ill to participate any longer, 3 did not give their consent, and 1 moved abroad).

Materials

Explicit memory. The Couples Test is a paired-associate learning task in which subjects have to memorize pairs of coupled names (Names subtest) or pairs of coupled faces (Faces subtest). The test is conventional in the sense that it only consists of male-female couples.

Materials: In the Faces subtest 10 photographs of male faces and 15 photographs of female faces, 10 stimuli and five distracters, are used. The faces do not have distinctly outstanding features that might serve as memory cues. In a pilot study (unpublished data), the most common faces were selected from a large set of photographs. The background in each picture is the same and all clothing is black. The names, also 10 male and 15 female, are common Dutch first names, with a maximum of two syllables. For both tests the ten male-female couples were randomly composed for the test.

Procedure: In a practice trial, two rather well known couples: Princess Diana & Prince Charles, and Queen Beatrix (the Dutch queen) & Prince Claus (her husband) are presented. The purpose of these simple practice items was not only for practice, but also to ascertain whether basic criteria, such as adequate vision, were met. If basic conditions were not met the test procedure was aborted. This happened in only one patient at T1 on the Names subtest. In the training phase the 10 fixed couples are presented in random order, for five seconds each. Subjects are instructed to memorize the couples. In the testing phase the 10 male stimuli are placed in front of the subject in a fixed order and the 10 female stimuli and five female distracters are presented to the subject. Subjects are instructed to place the females next to the males consistent with the couples they have memorized and to put the distracters aside. A forced guessing procedure was applied. The whole procedure, training and testing phase, was repeated in five successive trials. Delayed recall was tested after 25 minutes.

The Dutch version of the Rey Auditory Verbal Learning Test (RAVLT) is a test in which subjects have to learn 15 one-syllable words in five successive trials (Saan & Deelman, 1986). After 25 minutes free delayed recall was tested.

In this study the number correct per trial, the total immediate recall score (IR), the delayed recall score (DR), and an explicit learning index (trial 5 minus trial 1) on the RAVLT and the scores on both Couples Tests are used as explicit memory parameters.

Implicit Memory. The Picture Fragment Completion Task (Snodgrass & Feenan, 1990; Snodgrass & Vanderwart, 1980) is a computerized priming task. In this task people have to identify fragmented black and white line drawings. Each stimulus consists of eight levels of completion, with level one as the most fragmented and level eight as the completed figure. The task is preceded by three practice items, again both for practice and to ensure whether basic requirements to perform the test are met. All subjects met these criteria. In the training phase subjects have to identify 15 complete pictures (level eight) as fast as they can. Feedback is given, and wrong answers are corrected. After the training phase, a line bisection task (Schenkenberg, 1980) was administered in a short delay. The delay was followed by the testing phase in which a set of 30 fragmented pictures, each starting at completion level one, is shown: the 15 from the training phase (Old), and 15 new pictures (New). The subjects have to identify the pictures as fast as they can, and the level at which the item is identified correctly is recorded. The task consists of two parallel versions; pictures that are "new" in one version, are "old" in the other. Subjects are randomly given one of the versions of the test. The implicit memory thresholds (T= level of fragmentation at which the picture was identified) were transformed to proportions by the formula (9-T)/8 (Snodgrass & Feenan, 1990). Priming is defined as the difference in the number of steps needed to identify the new and the old pictures in the testing phase (Savings).

Procedure

The assessment of learning was part of a larger neuropsychological study, and was administered in two sessions. The first session took place at the participant's home; the second at the University Hospital in Groningen. Participants who were not able to come to the hospital were again visited at home. The first assessment, T1, took place in the subacute stage post-stroke (mean= 132 days, sd= 34, range: 72-233). One year later, at T2, the procedure was repeated (stroke-T2: mean= 558 days, sd= 56, range: 479-848). The control group was assessed with the same time interval (T1-T2: mean= 21 days, sd= 45, range: 354-630). The priming task as described here was administered in the chronic phase at T2 in 50 patients and 39 control subjects. This selection was random, and was caused by practical problems with the test.

Statistics

The retest reliability of the Couples Test was assessed (Pearson's correlation) for the total immediate recall scores (IR) on the Names and the Faces subtest. Moreover, in the control subjects at baseline (T1) the correlation between the Faces and Names subtest and the RAVLT was computed as a measure of construct validity, and differences between the performances on the Faces and the Names were tested (paired t-test).

To investigate the differences in learning between the patients and control subjects, GLM (General Linear Model) for repeated measures was performed, with Trial (the 5 learning trials) and Time (T1 versus T2) as within group variables, and Group (patients versus control subjects) as between group factor. Age was entered as a covariate in the explicit memory analyses. Aging is known to decrease explicit memory capacities, and to relatively spare implicit learning (Grady, et al.,1995; Jelicic, Craik, & Moscovitch, 1996). An interaction between the effect of age and of stroke on explicit memory functioning would be interesting. Whenever the sphericity assumption was not met, the Greenhouse-Geisser correction for degrees of freedom was applied. The delayed recall was also analyzed using GLM for repeated measures with Delay (trial 5 versus delayed recall) and Time as within group variables, Group as between group variable, and Age as the covariate. The same analyses were conducted investigating the differences between left and right hemisphere patients, with Side (left versus right hemisphere) as between subject variable. In these last analyses only the main effect of, and the interactions with Side were of importance to test the differences between both patient groups.

Implicit memory differences between the subjects were tested using ANOVA and the presence of a priming effect was analyzed with paired samples t-tests. To determine whether implicit and explicit memory were correlated, Pearson's correlation coefficient was computed for the priming score and the explicit learning scores.

An alpha level of .05, two-tailed, was used for all statistical analyses.

Results

Subject characteristics

The subject characteristics are presented in table 1. The groups did not differ with respect to age gender or education. Moreover, the left and right hemisphere patients did not differ significantly in ADL-functioning as measured with the Barthel Index (Mahoney & Barthel, 1965), which gives an indication of stroke severity (MannWhitney, p= .11).

Table 1 : *Subject characteristics.*

	n	**Age** *mean (sd)*	**Gender**	**Education** # *mean (sd)*
RH-patients	36	64.7 (9.9)	male 67%	3.9 (1.5)
LH-patients	40	63.7 (11.5)	male 65%	3.9 (1.2)
Controls	64	66.6 (11.9)	male 58%	4.2 (1.4)
Group comparison		*ANOVA* F= .90 p= .41	*Chi-square* χ^2 = 0.96 p= .62	*Kruskal-Wallis* H= 1.19 p = .55

Educational level was rated on a 7-point scale, ranging from 1, less than 6 years of education, to 7, university degree (Verhage, 1964).

Test characteristics

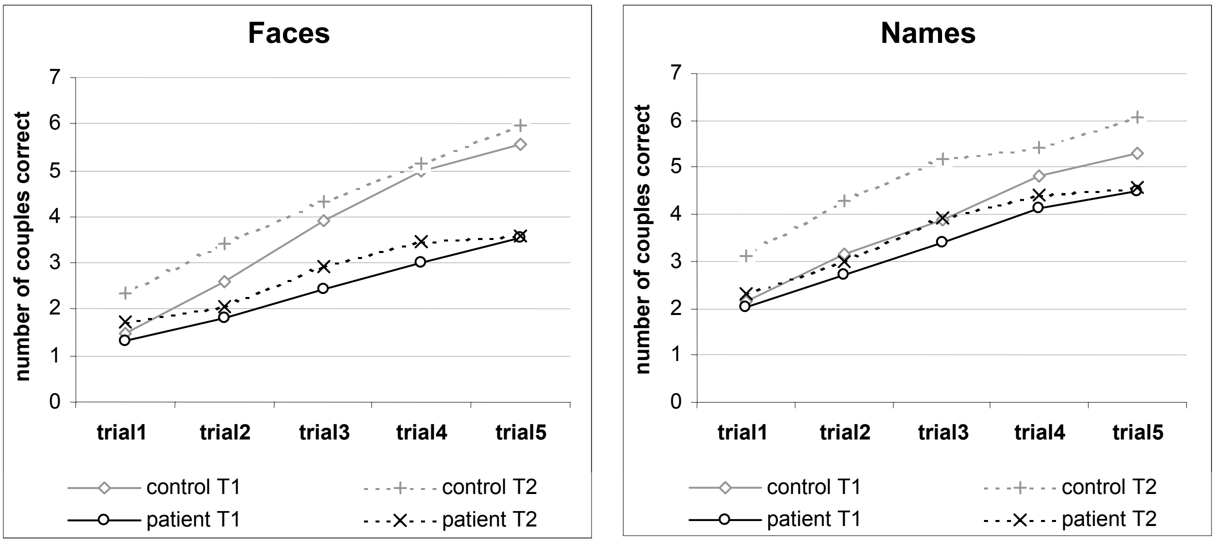
According to the data from the control subjects, the two subtests, Faces and Names, did not differ in difficulty at baseline (t= -.82, p= .42). Moreover, both the Faces (r= .65) and the Names (r= .59) total scores were significantly correlated to the RAVLT score. The retest reliability of the Couples Test appeared to be good (control subjects: Faces r = .88, Names r = .79; patients: Faces r = .84, Names r= .81).

Explicit learning

In the Couples test and the RAVLT the covariate age proved to be an important predictor of test performance (Faces: F(1, 127)= 115.00, p < .001; Names: F(1, 121)= 20.48, p < .001; RAVLT: F(1, 126)= 36.86, p< .001). Age interacted significantly with the learning curves on the Faces subtests and the RAVLT (respectively: F(2.99, 379.74)= 27.81, p< .001; F(2.64, 332.84)= 4.21, p< .01), but not with the Names subtest.

The learning curves of the patients and the control group, corrected for age, are presented in figure 1.The explicit memory tests did show a significant overall learning effect (Faces: F(2.99, 379.74)= 54.26, p< .001; Names: F(2.92, 352.79)= 22.98, p< .001; RAVLT: F(2.64, 332.84)= 33.78, p< .001). The patients had lower overall memory scores than the control subjects (Faces: F(1, 127)= 29.97, p< .001; Names: F(1, 121)= 5.29, p= .02; RAVLT: F(1, 126)= 6.73, p= .01). On the Faces subtest a significant interaction Trial x Group (F(2.99, 379.74)= 13.30, p< .001) indicated that the control subjects had steeper learning curves than the patients. This was, however, not the case with the Names subtest and the RAVLT. Although the patients were unable to remember as many words as the control subjects, the learning curves appeared to be parallel.

Looking at the course from T1 to T2, the Faces subtest was the only test that showed a main effect Time ($F(1, 127)= 10.81$, $p< .01$). The overall performances on the Names subtest and RAVLT did not change over time. There was a significant interaction Time x Group ($F(1, 121)= 6.16$, $p= .01$) on the Names subtest only; the control subjects improved more than the patients from T1 to T2.



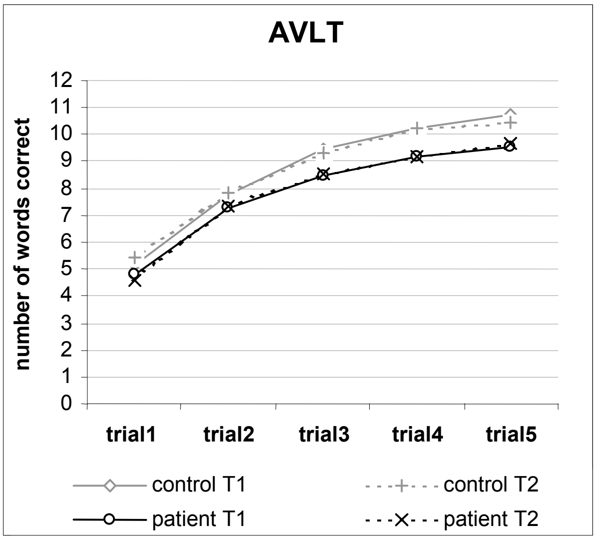


Figure 1: *The learning curves on the explicit memory tests, corrected for age, for the patients and the control subjects at T1 and T2.*

Explicit learning: forgetting

The covariate Age had a significant effect on the test scores at trial 5 and the DR, in all three tests (Faces: $F(1, 127)= 89.38$, $p< .001$); Names: $F(1, 120)= 18.66$, $p< .001$; RAVLT: $F(1, 124)= 20.77$, $p< .001$). No main effect Delay was found in any of the tests, indicating that the number of items that was remembered at delayed recall did not differ significantly from the number of items at trial 5. There was no interaction Delay x Group. The Names subtest, however, showed a significant three-way interaction: Delay x Group x Time ($F(1, 120)= 5.71$, $p= .02$);

the 'forgetting-curve' was steeper in the patient group at T1, but steeper in the control group at T2.

Explicit learning: side of lesion

There were no differences between left and right hemisphere patients in the total scores and the learning curves of the Couples Test and the RAVLT, at both T1 and T2. In general, the same was true for the number of items that was forgotten after 25 minutes; the delayed recall. There was only one significant interaction Time x Side: ($F(1, 68)= 10.29$, $p= .02$) on the Faces subtest. The right hemisphere group performed better at T1, whereas the left hemisphere patients performed better at T2.

As mentioned, there was no difference in difficulty between the Names and Faces subtest as measured in the control group at T1 ($t= -.82$, $p= .42$). Both left ($t= -2.07$, $p= .05$) and right ($t= -.54$, $p= .02$) hemisphere patients appeared to perform better on the Names subtest than on the Faces at T1. At T2 this difference had disappeared in the left hemisphere group ($t= -1.58$, $p= .12$), remained in the RH group ($t= -2.49$, $p= .02$), and occurred in the control group ($t= -2.52$, $p= .01$).

Explicit learning: memory and age

In the repeated measures analyses, age had proved to be an important factor predicting explicit memory functioning. Firstly, the correlations between age and the total immediate recall (IR) and the delayed recall (DR) are presented in table 2. Except for the correlation between age and the delayed recall on the RAVLT, all correlations are lower in the patient group.

Table 2: *Correlations between age and explicit memory scores.*

	T1		**T2**	
	Control	**Patient**	**Control**	**Patient**
Faces IR	-.74**	-.58**	-.73**	-.55**
Faces DR	-.71**	-.31** [1]	-.63**	-.32** [1]
Names IR	-.51**	-.21	-.47**	-.21 [1]
Names DR	-.46** [1]	-.18 [1]	-.35** [1]	-.27*
RAVLT IR	-.57**	-.40**	-.54**	-.33**
RAVLT DR	-.31*	-.33**	-.46**	-.31**

* $p< .05$, ** $p<.01$

Pearson's coefficients for the normal distributed data and Spearman's rho [1] for the others.

Next, the patient and control group were split into older (≥ 70 years) and younger (≤ 60 years) subjects. In order to avoid adjacent age groups, the subjects who were aged between 60 and 70 (patient n= 25, control n= 17), were excluded. The older group consisted of 25 patients (age: mean= 76, sd= 3.3), and 28 control subjects (age: mean= 78, sd= 4.9). The younger group contained 26 patients (age: mean= 52, sd= 6.0) and 19 control subjects (age: mean= 52, sd= 6.2). There were no differences in gender and education between patients and control subjects in the two subject groups. Univariate analyses (ANOVA) for the IR and DR scores were conducted, and the data are presented in table 3.

The performances of the older patients and the control subjects did not differ significantly on any of the IR or the DR scores, nor were any tendencies observed. On the other hand, in the younger group most parameters showed significant differences favoring the control group.

Table 3: *Comparison of 'young' and 'old' patients versus 'young' and 'old' control subjects (ANOVA) IR = immediate recall, DR = delayed recall.*

			Patient *M (SD)*	**Control** *M (SD)*	**F (df)**	**P**
'Young' <= 60 years						
T1	*Faces*	*IR*	16.9 (9)	26.7 (9)	12.9 (1,41)	**<.01**
		DR	4.8 (3)	8.0 (2)	12.7 (1,41)	**<.01**
	Names	*IR*	19.3 (9)	27.8 (13)	6.1 (1,39)	**.02**
		DR	4.8 (3)	7.1 (3)	5.8 (1,39)	**.02**
	AVLT	*IR*	43.4 (11)	48.6 (8)	2.8 (1,39)	.10
		DR	8.7 (3)	9.8 (2)	1.5 (1,38)	.23
T2	*Faces*	*IR*	19.4 (12)	32.0 (8)	15.9 (1,43)	**<.01**
		DR	4.9 (3)	7.8 (3)	10.0 (1,43)	**<.01**
	Names	*IR*	21.1 (10)	30.6 (15)	5.9 (1,40)	**.02**
		DR	5.1 (3)	6.6 (4)	2.2 (1,40)	.14
	AVLT	*IR*	43.7 (11)	48.7 (10)	2.3 (1,40)	.14
		DR	9.0 (3)	10.3 (3)	1.9 (1,40)	.18
'Old' >= 70 years						
T1	*Faces*	*IR*	8.9 (6)	8.6 (6)	.03 (1,46)	.87
		DR	2.8 (3)	2.3 (2)	.49 (1,46)	.49
	Names	*IR*	15.3 (10)	13.6 (9)	.46 (1,46)	.50
		DR	3.6 (3)	3.4 (3)	.05 (1,46)	.83
	AVLT	*IR*	34.7 (9)	36.5 (9)	.55 (1,50)	.46
		DR	6.7 (3)	7.5 (3)	1.07 (1,50)	.31
T2	*Faces*	*IR*	9.8 (6)	10.3 (6)	.08 (1,49)	.78
		DR	2.8 (2)	2.4 (2)	.53 (1,49)	.47
	Names	*IR*	15.3 (9)	16.4 (10)	.167 1,47)	.69
		DR	3.3 (2)	3.6 (3)	.09 (1,46)	.76
	AVLT	*IR*	34.5 (11)	35.8 (9)	.23 (1,50)	.64
		DR	6.5 (3)	7.4 (3)	1.14 (1,50)	.29

Implicit learning

Paired samples t-test showed a significant priming effect in both patients and control subjects (patient: t= -5.33, p< .001; control: t= -6.74, p< .001). So, both groups needed fewer steps to identify the old than the new pictures in the testing phase.

As is shown in table 4, the patients and control subjects did not differ from each other. Besides, there were no differences between the left and right hemisphere patients.

Table 4: *Comparison of patients versus control subjects, and right (RH) versus left (LH) hemisphere patients on the priming task (ANOVA).*

	Patient		**Control**	**F df (2,85)**	**p**
	RH	*LH*			
Old	.53	.51	.53	.09	.918
New	.44	.44	.45	.24	.715
Savings	.10	.07	.08	.404	.669

The implicit memory thresholds were transformed to proportions by the formula (9-T) / 8 (T= level of fragmentation at which the picture was identified) (Snodgrass & Feenan, 1990).
Savings= Old – New.

Explicit and implicit learning

In correlating implicit and explicit learning, we used the savings for implicit learning and the explicit learning effect (trial 5 minus trial1) at T2. The correlations were very small (maximum: r= .14), and none of them reached significance.

Conclusions & discussion

The aim of this study was to gain more insight into memory functioning following ischemic stroke. We studied explicit and implicit learning in a community-based patient group, with clinically diagnosed first-ever-unilateral ischemic stroke in the subacute (T1) and chronic (T2) stage. We were especially interested in the differences between left and right hemisphere patients and therefore constructed a paired-associate learning task with a verbal (Names) and non-verbal (Faces) subtest following the same paradigm. This test, the Couples Test, did measure learning over the five consecutive trials, had good retest reliability, and correlated reasonably well with the well-known Rey Auditory Verbal Learning Test (RAVLT).

Before interpreting the data we want to stress some important considerations with respect to the subjects in this study. We attempted to examine a community-based patient group that was not biased by a specific clinical setting. Therefore, on average, the patient group might be less damaged than the patients in several other studies. The control group was recruited in the same way as the patients, and might perform less well than a group of volunteers recruited by, for example, an advertisement. Next, a selection might have occurred due to subject-dropout between T1 and T2. Indeed, testing revealed that the patients who participated only at T1 were older (t= 2.67, p< .01), and had lower total memory scores (Faces: F(1,83)= 5.63, p= .02; Names: F(1,73)= 11.74, p< .01; RAVLT: F(1,79)= 21.58, p< .001). Finally, a selection bias may have been caused by the

GPs, who were trying to protect the most severely damaged patients by not referring them to this study.

Another important point of consideration is that, although all subjects clinically suffered a first-ever stroke, 27% (n= 18) of the patients for whom scan data were available (n= 68) appeared to have had previous silent infarctions. Those patients who appeared to have bilateral cortical lesions were excluded from this study. Scan data for the control group were not available, but in a large (n= 1077) population-based cohort scan study, one or more infarcts were seen on MRI in one quarter of subjects, most of whom had not experienced any symptoms (Vermeer, Koudstaal, Oudkerk, & Hofman, 2002). To check the possible effect of previous infarctions in our patient group an ANOVA was conducted on the Couples test and the RAVLT. No significant differences between the patients with and without previous infarctions were found.

Comparing stroke patients and control subjects at T1 and T2 revealed that the stroke patients had lower immediate and delayed memory scores on all three tests. Although patients were unable to remember as many items as the control subjects, the learning curves appeared to be parallel for the two verbal memory tests: the Names subtest and the RAVLT. The Faces subtest was the only test that revealed a significantly steeper learning curve in the control group compared to the stroke patients. Moreover, no significant loss of information from memory in either the patients or the control subjects was demonstrated in the delayed recall. So, although the patients were unable to remember as many items as the control subjects, they were capable of learning and retaining this information for at least 25 minutes.

The second finding was the importance of the Age factor in immediate as well as delayed recall. Remarkably, the relative impact of stroke on explicit memory functioning was much stronger in the younger patients. Younger patients appeared to have memory impairments on both the Names and Faces subtests as compared to the younger control subjects. The older patients on the other hand, did not show significant memory deficits as compared to their age-matched control group Johnstone et al. (1998) found similar results for intellectual functioning in a patient group with traumatic brain injury. Moreover, in a recent animal study, young rats showed better memory performance in a water-maze than old rats, but when ischemic rats were compared to non-ischemic rats within the same age group, the memory impairment appeared to be more pronounced in the young ischemic rats (Shapira, Sapir, Wengier, Grauer, & Kadar, 2002).

Between the subacute and chronic stage after stroke, no recovery of explicit memory function was found. The observed improvement on the Faces subtest was not different for patients and control subjects, and can therefore not be attributed to recovery of function in the stroke group. On the Names-subtest the patients showed even less improvement than the control subjects did. Neither group scored higher on the RAVLT when retested after one year. Apparently, if any recovery of memory had taken place in this stroke group, it occurred before the fourth month post-stroke.

The Couples Test was designed particularly to compare the performance of the left and right hemisphere patients, but no clear differences between these patient groups was found. In agreement with Steward et al. (1996), we found right hemisphere patients to have more difficulty remembering faces than names at both T1 and T2. However, at T1 the same was true for the left hemisphere patients and at T2 for the control subjects. A decreased ability to remember faces was thus not specific for the right hemisphere patients in this study.

In a review by Cabeza and Nyberg (2000) of 275 PET and fMRI studies, episodic memory was discussed in terms of encoding and retrieval. Although clear lateralisation effects were found in encoding tasks, the same was not true for retrieval tasks. In encoding there was a clear pattern of lateralisation in the medial temporal activations: verbal materials were lateralized to the left, and non-verbal materials to the right. Verbal materials were also always left lateralized with respect to the prefrontal activation. However, non-verbal stimuli such as, for example, unfamiliar faces, were associated with right prefrontal activations in one study (Kelley et al., 1998), and left lateralized activations in another (Haxby et al., 1996). Killgore, Casasanto, Maldjian, and Detre (2000) showed that when the encoding of paired faces was contrasted with memory for individual faces, a left lateralized network of limbic structures was activated. During retrieval many brain structures appeared to be involved, including prefrontal, medial-temporal, medial parieto-occipital, lateral parietal, anterior cingulate, occipital, and cerebellar areas, but no clear lateralisation of activations with respect to verbal versus non-verbal materials was found (Cabeza & Nyberg, 2000).

The lack of differences in memory performance found in our study with respect to lesion lateralisation are not in conflict with these imaging data. Although the left and right hemispheres are specialized with respect to the modality of the material, for verbal more clearly than for non-verbal, this accounts only for part of the memory process. The Couples Test is a paired-associate learning test in which, similar to the RAVLT, encoding as well as retrieval and recognition are involved, but cannot be analyzed separately. Therefore, no conclusions can be drawn about the lateralisation of these separate processes, but, at the task level, no differences between our LH and RH patients could be observed.

The priming effect found in this study appeared to be intact after stroke. Furthermore, no correlation was found between explicit and implicit learning. These findings were consistent with expectations based on earlier studies (Cooley, Stringer, Hodnett, 1997; Curran, Schacter, & Gallucio, 1999).

The present study showed explicit, but no implicit memory impairments in relatively mild unilateral ischemic stroke patients compared to control subjects. These impairments did not improve between the subacute and chronic stage post-stroke. The data suggest that, although older patients obtained the lowest memory scores, the impact of stroke on memory function was stronger in younger patients.

The traditional distinction between left and right hemisphere patients with respect to impairments in respectively verbal and non-verbal memory could not be confirmed.

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